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## (54) INTERNAL LINING AND SEALING OF HOLLOW DUCTS

(71) I, LOUIS ANTHONY RALPH ROSE, of 54 Llanvair Drive, South Ascot, Berkshire, a British subject, do hereby declare the invention, for which I pray that a patent  
5 may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:

The present invention relates to methods  
10 and devices for applying linings to the interior surfaces of pipelines *in situ* for the purpose of sealing leaks, and for certain associated or similar tasks. The invention is applicable to pipelines carrying fluids  
15 under pressure and is particularly applicable to gas mains.

Quite commonly during the lifetime of a pipeline deterioration of its inner surfaces takes place as a result of attack by organic  
20 and inorganic matter as in the case of water mains, or by moisture or acids borne in the fluid stream in a gas main.

Similarly deterioration in the effectiveness to withstand leakage of the joints connecting adjacent sections of pipeline takes place  
25 as a result of ground movement due to subsidence or traffic vibration, inherent bad workmanship or defective materials. Also in the case of socket and spigot joints which  
30 have been sealed with yarn and lead, the effect of transporting dry natural gas in place of moist town gas causes drying out and shrinkage of the yarn leading to the creation of leakage fissures.

Where a wedge-shaped rubber sealing ring has been used in a socket and spigot joint in a gas pipeline, moisture and sol-  
35 vents carried by town gas have aided the effectiveness of sealing. On the introduction of dry natural gas a drying-out and shrinkage of the rubber rings has been occasioned, leading to leakage from the joint.

In the cases cited, severe leakage becomes  
40 a problem.

Various methods of combatting the pro-  
45 [Price 25p]

blems of surface deterioration and or joint leakage have been devised employing spray-  
ing techniques, smearing with a sealing compound, flooding the pipeline with a  
5 sealing fluid followed by pressurisation and drainage of the line, mechanical and hand  
trowelling of sealing compounds employing cements or mastics and, on large mains, by  
manual injection of a sealing compound.

However, all these methods are either  
55 time-consuming or extravagant of sealing compound.

Accordingly, the invention provides a method of lining the inner surface of a  
60 cylindrical pipeline comprising inserting into the pipeline a tubular, flexible, impermeable membrane in a collapsed state, ex-  
panding the membrane by injection of a fluid until the membrane lies adjacent said  
65 surface, and causing the membrane to adhere to the surface over only the upper part thereof by means of an adhesive.

The invention also provides apparatus for use in the aforesaid method comprising a  
70 container for holding the flexible tubular membrane, the container being supported on wheels adapted to run on the walls of the pipeline and means for paying out a  
flexible tubular membrane in a rearward  
75 direction relative to the direction of motion of the container.

The invention may be used to prevent the deterioration of the internal surface of pipes  
80 or pipelines and/or the leakage, from joints, of the transported fluid.

The invention may be used to provide an internal lining to pipes prior to assembly to  
85 form a main or pipeline and is not limited to gas pipelines but may also be applied to water mains or other pipelines.

In essence the invention provides for the positioning of a thin, continuous and complete membrane in intimate contact with  
90 the inner surface of a length of pipeline, such that all inner surfaces of the pipeline

are completely divorced from the fluid transported and so that all joints or porous regions are bridged or shrouded by the membrane which forms a complete barrier to the egress of fluid.

A further development of the invention also provides for a method of handling the membrane as manufactured in order that its shape and condition should be made suitable for use as desired and for a device comprising several parts for positioning the membrane as described.

The membrane to be used is preferably a continuous, seamed or seamless tube having very low ratio of wall thickness to diameter, preferably such that the tube could be folded easily in any plane.

The external diameter of the membrane tube is preferably approximately equal to the nominal internal diameter of the pipeline into which it was to be fixed.

The material used for the manufacture of the membrane would be selected to suit the fluid transported in the pipeline to be treated, factors such as relative permeability, compatibility and neutrality being taken into account.

A suitable seamless tube can be manufactured by extrusion of a suitable plastics, rubber or similar material. Alternatively, a tube can be knitted using a suitable thread, the hose produced being made impervious by coating or impregnation by suitable rubber or plastics compounds.

Two methods of positioning the membrane inside the pipeline to be lined and sealed can be used.

In the first the tube is pulled into and through the pipeline by cord or rope. On completion of the pulling-through operation the ends of the tube are secured by bonding or other means to the ends of the length of pipeline under treatment.

If then the two ends of the pipeline are sealed to the atmosphere and pressurised air supply is fed to the interior of the tube, the tube is inflated and brought into contact with the inner surface of the pipeline. Vents in the pipeline permit air entrained between the outer surface of the membrane and the pipe to escape.

With a suitable adhesive previously applied only to the upper interior surfaces of the pipeline or to the top external surface of the membrane (or to both pipe and membrane) permanent attachment of the membrane to the pipe is achieved.

This first method would generally be suitable for use on short lengths of pipeline. On long lengths, the membrane may be excessively stressed due to the tensile forces imposed on it.

The second method of locating and securing the membrane tube in position is more suitable for the treatment of long lengths of

pipeline.

In this method, the tube, folded after manufacture and packed into a carrying device, is pulled or propelled through the pipeline dispensing the membrane tube progressively.

The first method mentioned needs little elaboration. The second method will now be described in detail with reference to the accompanying drawings.

Figures 1 to 6 show various stages in a method of packing a membrane tube in a container;

Figure 7 shows a section through a pipeline with a container moving through;

Figure 8 shows an end view of the container of Figure 7 in the pipeline; and Figure 9 shows the treatment of a buried pipeline.

Figure 1 shows a thin-walled membrane tube 11 of circular section. By axial and progressive movement the tube is drawn through a former of initially square or rectangular section 12, being held in this shape either by suction through slots 13 in the walls of the former, or by internal inflation by air.

At this stage two opposing surfaces 14 are coated with a suitable adhesive by brush or spraying. The adhesive selected is of a type which is unsuitable for permanent adhesion to a liketreated surface, and serves only to assist the packing operation.

Following this the tube 11 is drawn further into the former, which remains of constant width whilst reducing in height to form a symmetrical taper as shown in Figure 4 in perspective view.

Vacuum application to or internal inflation of the surfaces free of adhesive is maintained at this stage whilst air under slight pressure supplied through ducts 15 cause the adhesive treated surfaces to deflect and fold inwards as depicted in Figure 3. The slight air pressure supplied through ducts 15 supplements the deflection inwards of the membrane which would be forced to assume the shape of the former 12.

On leaving the former, rollers 16 (Figure 5) compress the folded tube into a thin rectangular section. It will be seen that the two adhesive coated surfaces 14 have each been folded inwards and held together temporarily for ease of handling.

When folded as described, the width of the flattened membrane tube will be seen to be approximately equal to a quarter of the circumference of the original round-sectioned tube.

The flattened coil is now folded alternatively to the left and right in equal lengths 21, in a manner suitable for packing it in a container 20 (Figure 6).

However, other methods of folding the

tube may be adopted in order that it may be easily stored in the container. Figures 3 and 4 depict a former 12 capable of producing a flattened tube having a width equal approximately to a quarter of the circumference of the original membrane tube. By providing more than one recess or indentation to each of the sides of the former 12 it is possible to produce a flattened tube having a width less than a quarter of the original tube.

Thus a former 12 with two indentations to each of its sides will produce a flattened tube having a width equal approximately to a sixth of the circumference of the original membrane tube.

The thickness of the flattened tube 11 as shown is approximately equal to four times the wall thickness of the membrane. The lengths 21 of the folds will be limited by the dimensions of the container 20, the dimensions of which in turn will be dependent on the internal diameter of the pipeline to be treated and through which the container is to be drawn or propelled.

For a 12" diameter pipeline, the folds 21 of the flattened and folded membrane tube may be approximately 7". If the membrane has a thickness of  $\frac{1}{4}$ ", a section of pipeline about 1,000 ft. in length can be treated using a container 20 only 9 ft. long.

Figures 7 and 8 depict a carriage comprising the container 20, into which a flattened tube has been packed, in position in a pipe 22.

An arrow 23 indicates the direction of movement of the container 20 through the pipe. The means by which the container is propelled through the pipe are not shown.

At the leading end of the container 20 a clamp 24 holds the free end of the flattened tube 11 securely. The other end of the container is equipped with dispensing rollers 25 through which the tube is placed during the container packing operation. The rollers 25 are actuated through drive chains or bands 26 by other rollers 27 in frictional contact with the pipe wall. The drive chains or bands 26 are crossed as depicted to effect correct rotational movement of the rollers.

In forward motion of the container 20, the flattened coil 11 is paid-out or dispensed into the pipe 22 by the action of the rollers 25.

The driving rollers 27 and the dispensing rollers 25 are connected to the container 20 by radiusing linkages 28. The forces necessary to keep the rollers 25 in contact with the flattened membrane tube 11 and the rollers 27 in frictional contact with the pipe wall are provided by the compression springs 29.

To ensure that the flattened tube 11 is laid in the pipe such that its horizontal axis

at any section is always parallel to the horizontal axis of the pipe, two sets of wheels 30 on the underside of the container 20 are mounted on struts 31 inclined both laterally of the centre vertical axis 32 of the container, and backwardly of its direction of movement 23.

The inclined struts 31 ensure that the wheels 30 provide a castoring action and prevent the container from climbing the walls of the pipe.

The base of the container 20 is provided with weights 33 which together with the castoring action of the wheels 30 ensure that the vertical axis 32 of the container remains in the vertical plane during its progress through the pipe.

The container 20 may be made from a flexible material, such as a semi-rigid plastics, in order that curves or bends in a pipeline can be negotiated with the minimum of resistance.

Also the container may be provided with tension-mounted wheels 34 on its sides and top to limit any tendency for it to sway during forward progress. It has such cross-sectional dimensions as are necessary for holding a folded membrane tube 11 suitable for a particular diameter of pipeline. The container may also be made in tubular form without wheels. The folded membrane tube would be stored in a rectangular shaped space in the container. On the lower surface of the folded membrane tube and the wall of the tubular container, weights would be provided in order that correct orientation of the horizontal axis of the container be maintained during its forward progress through a pipeline. The length of the container 20 may be determined in any instance by the length of folded tube to be stored which in turn would be related to the length of pipeline to be treated. Variations in the length of a container 20 may be made by joining together lengths of container wall by flanged joints or other suitable means.

The leading end of the container is fitted with a towing eye 35 to which towing means (not shown) may be attached.

At the following or dispensing end of the container 20 and connected to it by means (not shown) is a membrane tube expander 36. The flattened membrane tube 11 is threaded through a rectangular slot 37 at the front end of the expander and having its major axis coincident approximately with the horizontal axis of the pipe. The other end 38 of the expander is of circular cross-section, having an external diameter approximately equal to the internal diameter of the pipe being treated.

The expander 36 may be constructed from a suitable plastics material having semi-rigid characteristics. If required an adhesive dispenser or spray for treating the

walls of the pipe could be attached to the front end of the expander 36.

The method of operation will now be described with reference to the buried pipeline shown in Figure 9.

Access pits 40 and 41 are shown at each end of a length of pipeline 42. Portions of pipe have been removed for the purpose of gaining access to the interior.

Prior to the application of the lining and sealing membrane tube the interior of the pipe would require to be drained and the inner surfaces cleaned of debris, rust, growths, etc., by means commonly employed for such purposes.

After cleaning, the upper part of the interior surface of the pipeline may be coated with a layer of adhesive. The use and choice of an adhesive or other suitable fluid would be dependent on the material selected for the membrane tube.

In one method, the inner surface of a pipeline may be coated with a fluid of a type which would interact chemically with a second fluid applied to the outer surface of the membrane tube. Alternatively, the pipe surface and/or the membrane tube may be coated with adhesive or cement or a type which on being allowed to dry has the ability to form a bond following the application of pressure.

Referring to Figure 9 the flattened membrane tube 11 is depicted as having been passed through the rectangular slot 37 of the expander 36 and secured to the open end of the pipe 42 in the access pit 40.

The means by which the tube is to be secured to the pipe end is not depicted in the drawing, although the end of the flattened tube needs first to be opened out to a circular shape. The end of the pipe in access pit 40 is then sealed with a cap or plug and air under pressure is injected into the opened-out end of the membrane tube. As the container 20 moves along the pipe from the one access pit 40 to the other access pit 41 it will be seen that the flattened membrane tube 11 will be paid out into the expander 36. The air pressure causes expansion into a circular shape of the the membrane tube 11 between the sealed end of the pipe 42 and the expander 36.

Under continued air pressure the outer surface of the membrane tube is brought into intimate contact with the internal surface of the pipeline. The force applied to the inner surface of the membrane tube 11 by the air pressure must be of adequate intensity to ensure adhesion of the tube to the upper part of the wall of the pipe 42 by virtue of the adhesive used.

If required, a cylindrical plunger 44 of a flexible material, which is capable of being compressed and propelled by air pressure

can be used to produce intimate and forceful contact of the membrane tube with the pipe surface, and thus effect absolutely secure adhesion.

On reaching access pit 41 the container 20 is removed from the pipeline and the end of the flattened membrane tube 11 released from the clamp 24. By manual manipulation the end of the flattened membrane tube 11 is re-formed into a circular shape and attached to the end of the pipe 42 in the pit 41. At this stage the plunger 44 if employed, is withdrawn from the inside of the membrane tube.

The membrane tube would then have been applied continuously from one access pit 40 to the other access pit 41.

Prior to the lining and sealing processes as described to a selected length of pipeline, a pressure test would be applied to determine the degree of leakage of the section. After lining, a further pressure test would be applied to check the efficiency of the new lining prior to the section of pipeline being put back into service.

Since the membrane tube is attached at the top of the pipeline and left free at the bottom, there is no difficulty if the membrane tube were slightly too small in any particular case.

On gas and water mains serving consumers, connections are fitted to the main to effect individual supply. These connections which are constructed by drilling and threading small holes in the main invariably on its upper invert would be sealed off by the lining process described in this invention.

To re-form such outlets the newly placed membrane tube would require to be pierced.

The location and piercing of the outlets may be achieved following the lining process by propelling a device through the pipeline, the device being equipped with small rollers having diameters less than the sizes of the connection holes, with tensioning arms linking the rollers to the device such that in progress through the pipeline the rollers would be forced into contact with the lining.

A roller thus in contact with the membrane tube would be depressed into any outlet underlying the membrane tube. By means of an electrical or magnetic switch attached to the tensioning arm of the roller the progress through the pipeline of the device to which the roller was attached would be immediately halted by the movement of a roller into the cavity behind the membrane formed by the outlet.

By remote control from the exterior of the pipeline the roller in contact with the depression described would then be retracted and replaced by a piercing device operating on an arm swung to move into

the position previously occupied by the roller.

In another method the locating and piercing of the outlets may be achieved by propelling a device through the pipeline following the lining process, the device being equipped with a magnetic or ultrasonic sensing unit affixed to, but free to oscillate about the longitudinal axis of the propelled device.

The oscillatory movement would be restricted by a counter-weight, such that the magnetic or ultra-sonic sensing heads would scan the upper invert of the pipe.

The propelled device would be connected to electrical power and signal cables leading back to the end of the pipeline. In forward motion the magnetic or ultra-sonic sensing unit would emit either a magnetic field or an ultra-sonic pressure wave.

The magnetic wave or the ultra-sonic wave thus caused to focus on the upper invert of the pipe would give no reflective change in character unless broken by impingement on an outlet or connection to the pipeline.

In so doing the signal 'note' produced would alert the operator guiding the propelled device.

By remote control from the exterior of the pipeline the magnetic or ultra-sonic sensing device would be rotated and replaced in position by a piercing device, actuated to pierce the membrane and hence make an outlet to the connection.

By piercing the membrane the outlet to the connection is remade.

A summary of the uses to which the invention could be put is as follows: -

- (a) Lining of new pipes and pipelines.
- (b) Lining of old pipes and pipelines.
- (c) Re-lining of old pipelines.
- (d) Sealing of leaks in old pipelines.
- (e) Preventing the occurrence of leaks in pipelines and/or the deterioration of the surface of pipelines.

It may be used to apply more than one membrane lining to the same pipeline, the advantage of which would be to improve the strength of the pipeline by building-up several reinforcing layers of membrane of suitable material, thus effecting not only the establishment of a barrier to deterioration and leakage in a pipeline but an increase in the hoop strength of the pipeline. Thus, the working pressure of the fluid transported by the pipeline may be increased, resulting in an increase in volumetric flow or carrying capacity of the pipeline.

The membrane may be manufactured from a fine thread of high tensile material such as steel, glass fibre or nylon and formed by a knitting process to produce a hose which is then impregnated with a suitable compound to form an impervious and

continuous surface.

Use of such a membrane allows an extremely strong inner shell to be formed in a pipeline, producing the benefit of even greater improvements in pressure application and volumetric flow.

Thus, it will be seen that the invention may be used to up-grade the pressure and flow characteristics of an existing pipeline, which might or might not require also to be treated for the deterioration of its inner surfaces or its joints.

#### WHAT WE CLAIM IS:

1. A method of lining the inner surface of a cylindrical pipeline comprising inserting into the pipeline a tubular, flexible, impermeable membrane in a collapsed state, expanding the membrane by injection of a fluid until the membrane lies adjacent said surface, and causing the membrane to adhere to the surface over only the upper part thereof by means of an adhesive.

2. A method as claimed in Claim 1 wherein air is injected to effect said expansion.

3. A method as claimed in Claim 2 wherein the membrane is pressed firmly by the injected air into intimate contact with the surface over its whole circumference.

4. A method as claimed in Claim 1, 2 or 3 wherein it is ensured that air is not trapped between the outside of the membrane and the surface.

5. A method as claimed in Claim 4 wherein said membrane is partly coated externally with adhesive before insertion in the pipeline.

6. A method as claimed in Claim 4 or 5 wherein said surface is coated with adhesive before insertion of the membrane in the pipeline.

7. A method as claimed in any of Claims 1 to 6 wherein the membrane is inserted in the pipeline by pulling one end of the membrane through the pipeline, starting at one end of the pipeline, until said one end of the membrane lies at the other end of the pipeline.

8. A method as claimed in any of Claim 1 to 6 wherein the membrane is inserted in the pipeline by holding one end of the membrane at one end of the pipeline and moving the remainder of the membrane, held in a container, through the pipeline, paying out the membrane from the container until the other end of the membrane lies at the other end of the pipeline.

9. A method as claimed in Claim 8 wherein the membrane in the container is held folded in zig-zag fashion.

10. A method as claimed in any preceding claim in which the membrane is punctured at selected points after application to permit communication between the pipeline and apertures in the surface.

11. A method as claimed in any preceding Claim which is employed more than once in a single pipeline to provide a coating formed of a plurality of layers.

5 12. Apparatus for use in the method of Claim 1 comprising a container for holding the flexible tubular membrane, the container being supported on wheels adapted to run on the walls of the pipeline and  
10 means for paying out the flexible tubular membrane in a rearward direction relative to the direction of motion of the container.

13. Apparatus as claimed in Claim 12 wherein said wheels are on mounts which project rearwardly of said direction of  
15 motion.

14. Apparatus as claimed in Claim 12 or 13 wherein ballast weights are mounted in such a position as to maintain the apparatus upright when it is travelling through  
20 the pipeline.

15. Apparatus as claimed in any of Claims 12 to 14 wherein said means for

paying out includes a pair of adjacent rollers driven indirectly by friction wheels which are engageable with the walls of the  
25 pipeline through which the apparatus is passing.

16. Apparatus as claimed in any of Claims 12 to 15 which is articulated or flexible to allow the apparatus to pass along  
30 an elongated pipeline which is curved longitudinally.

17. Apparatus for lining the inner surface of a cylindrical pipeline substantially as herein described with reference to and as  
35 illustrated in the accompanying drawings.

18. A method of lining the inner surface of a cylindrical pipeline substantially as herein described with reference to and as  
40 illustrated in the accompanying drawings.

For the Applicant.

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FIG. 1

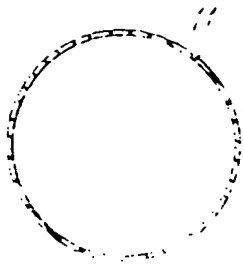


FIG. 2

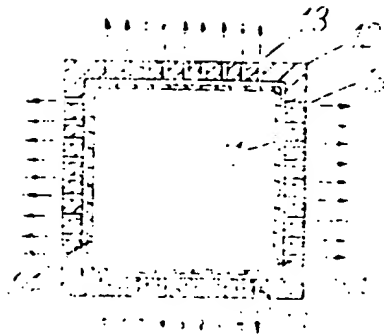


FIG. 3

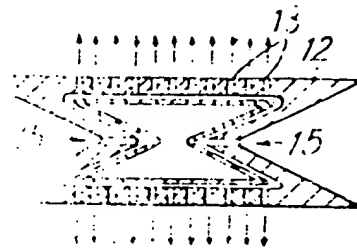


FIG. 5

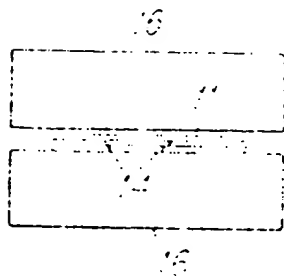


FIG. 4

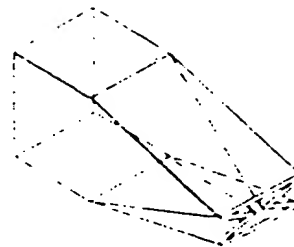


FIG. 6

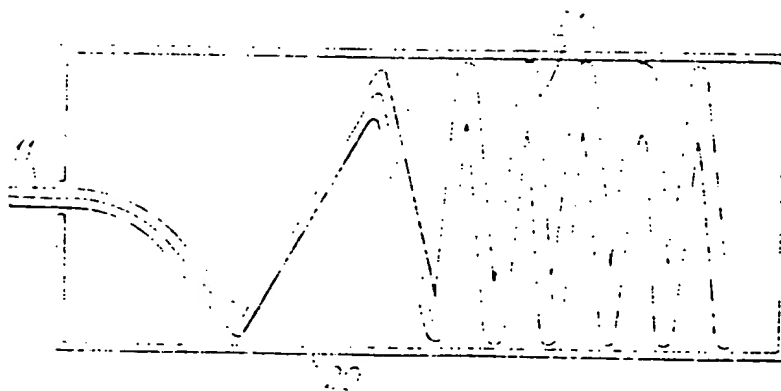


FIG. 7

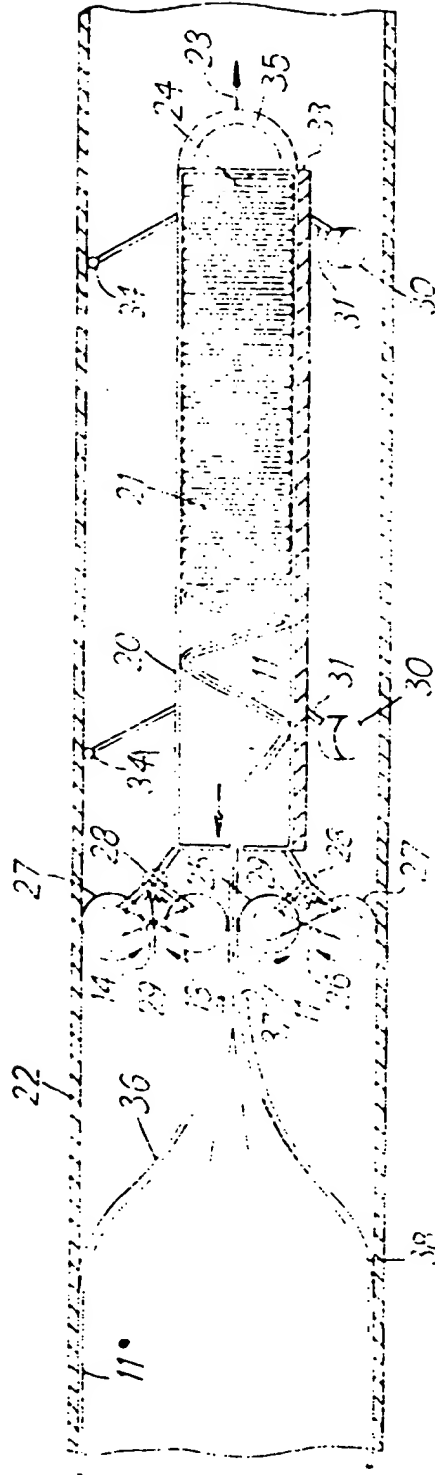


FIG. 8

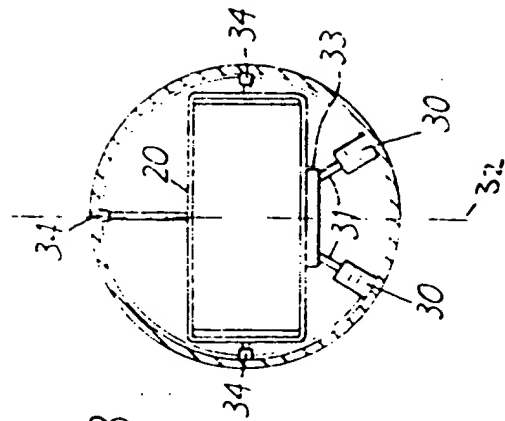


FIG. 9

